Design and synthesis of all organic polymer dielectrics for high temperature and high electric field application through molecular engineering approach

Ajinkya Deshmukh[1], Chao Wu[1], Zongze Li[1], Lihua Chen[2], Abdullah Alamri[1], Yifei Wang[1], Rampi Ramprasad[2], Yang Cao[1], and Gregory Sotzing[1]

1. University of Connecticut, Storrs, Connecticut, United States
2. Georgia Institute of Technology, Atlanta, Georgia, United States

Polymers with high electric field stability at ambient and elevated temperatures are important for various electrical and electronic applications. For capacitor applications, polymers need to have a high discharge density with high efficiency. However, at elevated temperatures, common high-temperature polymers show enhanced electrical conduction due to their low bandgap, which leads to low discharged energy density with high energy loss. At the same time, polymers with high bandgap and low loss at high electric fields cannot be used at elevated temperatures because of their low glass transition temperatures. For example, the state-of-the-art dielectric polymer that is BOPP can only be used up to 110 °C with cumbersome cooling.

To overcome this issue, we carefully studied the common polymers and explored an inverse correlation between Tg and bandgap for common polymers. Further, to break this design constraint, we developed a new polymer design strategy through a molecular engineering approach where high bandgap (~ 5 eV) and high Tg (~186 °C) can be obtained simultaneously. As a result, polymer synthesized using this new design strategy can be exposed to harsh conditions of simultaneous high temperature and high electric field. The synthesized polymer is then further characterized for capacitive energy storage purposes, and it shows a high discharged energy density of 5.7 J/cc at 150 °C, outperforming all the flexible polymer dielectrics. High bandgap, coupled with high Tg, leads to low electrical conduction loss and a combination of flexible and rigid segments in the polymer repeat unit leads to low dielectric loss. Additionally, the synthesized polymer can be processed into flexible free-standing films using a simple role to role process. The design strategy can be used for polymers for energy storage and for polymers for other electrical applications where low electrical conduction is desired.